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The Endogeneity of the Natural Rate of Growth – an Empirical Study for Latin-American Countries

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The Endogeneity of the Natural Rate of Growth – an Empirical Study for Latin-American Countries

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Abstract

The aim of this paper is to analyse the sensitivity of the natural rate of growth to the actual rate of growth for a sample of eleven Latin-American countries, assuming the natural rate to be determined endogenously by changes in the actual rate of growth. The natural rates of growth are estimated in a system of SUR estimations over the period 1986-2003. In order to determine whether they react endogenously to changes in the actual rate of growth, a dummy variable for boom periods is added to the system of regressions. In the second part of the empirical analysis, the direction of causality between input growth and output growth is then tested for four of the countries in the first sample. The results confirm not only the hypothesis about the endogeneity of the natural rate of growth, but also show causality from output growth to input growth to be much stronger than the reverse.

Keywords: Natural rate of growth, actual rate of growth, endogeneity, Granger causality, Latin America.

JEL classification: O40, E10, C23

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1. Introduction

In this paper, an empirical study is presented on a sample of eleven Latin-American countries about the behaviour of the natural rate of growth of these countries when subject to changes in the actual rate of growth. It refers to the paper "The endogeneity of the natural rate of growth" by León-Ledesma and Thirlwall (2002) who conducted a similar study on a sample of OECD countries. However, this paper takes their study one step further, because their assumptions will be tested employing SUR ('seemingly unrelated regressions') estimations as in Zellner (1962). Thus, not only can the results of the empirical study be expected to be more efficient than they would be when using individual OLS estimations, but it will also be examined whether the endogeneity assumption from León-Ledesma and Thirlwall also holds for less industrialised countries.

The aim of this paper is to question empirically the concept of the natural rate of growth being exogenous to changes in the actual rate of growth. Thereby, the idea of the existence of an exogenous growth frontier and the long-run convergence of the actual rate of growth to it, as claimed by mainstream neoclassical and 'endogenous' growth theory, is also questioned.

In contrast to old and new neoclassical growth theories, economic models by Kaldor (1957; 1966), with reference to the works of Verdoorn (1949) and Okun (1962), imply that growth is primarily driven by demand factors and both the labour force and economic productivity react positively to higher demand growth. This constitutes a natural rate of growth which reacts endogenously to changes in the actual rate of growth. As a result, it is not primarily supply growth which constrains the growth rate, but rather demand constraints related to high inflation and balance of payments disequilibrium which tend to occur before supply constraints are ever reached.

As an additional argument questioning the relevance of neoclassical growth theories, which fail to acknowledge the existence of demand constraints in the growth process, an analysis of the causality between input growth and output growth employing the concept of Granger causality is conducted after investigating the question of the endogeneity of the natural rate of growth. While mainstream growth theory claims that there exists only causality from input growth to output growth, it can be demonstrated that at least bi-directional causality between both factors can be found, with causality from output growth to input growth being stronger in the majority of the countries in the sample.

The paper is organised as follows: Theoretical aspects of the relationship between the natural rate of growth and the actual rate of growth in different growth theories are considered in section 2. After describing the model which is tested in the analysis in more detail in section 3.1, the empirical part of the paper (sections 3.2 – 3.4) then consists of the calculation of the natural rate of growth, the testing of its endogeneity with respect to the actual rate of growth (both using SUR estimations), and finally the Granger causality analysis for output and input growth. In section 4, the empirical results are interpreted and put in context with the economic development and situation in the countries of the sample during the time span covered in the analysis.

2. The role of the natural rate of growth in different growth theories

The concept of the natural rate of growth is of great theoretical importance and can be found in nearly all modern growth theories. It first appeared in Harrod's article „An Essay in Dynamic Theory" in 1939, where it is defined as the "maximum rate of growth allowed by the increase of population, accumulation of capital, technological improvement and the work/ leisure preference schedule, supposing that there is always full employment in some sense" (Harrod, 1939, p. 30). According to Harrod, the natural rate of growth sets the ceiling for long run growth in that it represents the long-run maximum rate of growth achievable in an economy. It also determines the maximum divergence between the actual and the warranted rate of growth, thereby creating cyclical downturns. Both major components of the natural rate of growth, the growth of labour productivity and the growth of the labour force, are treated as strictly exogenous. The warranted rate of growth responds only to changes in the savings ratio and the capital-output ratio. This is why Harrod finds no mechanism which will bring the warranted rate of growth into line with the natural rate and, thus, stresses the negative effects of a warranted rate above the natural rate of growth.[1] However, his focus is mainly on the investigation of possible causes for a divergence of the actual rate of growth from the warranted rate, resulting in a highly unstable system with no tendency towards equilibrium growth (Harrod, 1939; Harrod, 1973).[2]

In reaction to Harrod's dynamic theory, Solow (1956) constructed his model of economic growth in the mid-fifties. The model, however, focuses on the convergence of the warranted

[1] Interestingly, Hawtrey (1939) observes in his contemporary critique of Harrod's theory that although there may be inventions that decrease the amount of capital needed for a given output (resulting, in Harrod's model, in a warranted rate of growth which lies above the natural rate of growth), the amount of capital to be used by a certain labour force can be increased almost indefinitely. According to Hawtrey, the warranted rate of growth would therefore never rise above the natural rate, but rather converge to it.

[2] For further discussion of Harrod's growth theory see Hein (2004).

rate of growth to the natural rate, thereby ignoring Harrod's main instability problem. In accordance with Harrod, he assumes the warranted rate of growth to be determined by the savings ratio and the capital-output ratio. The natural rate is first defined as the growth rate of the labour force: "As a result of exogenous population growth the labour force increases at a constant relative rate *n*. In the absence of technological change *n* is Harrod's natural rate of growth." (Solow, 1956, p. 67) Later on, neutral and exogenous technological change is included in the model. Like Harrod, he thus assumes the natural rate of growth to be exogenous to the system. Steady-state growth will then be achieved through adjustment of the capital-output ratio, resulting in convergence of the warranted rate of growth to the natural rate of growth (Solow, 1956).[3]

While neoclassical growth models predicted the convergence of growth rates between different countries through capital flows from industrial countries to less developed countries caused by higher rates of return on capital in these countries, empirical studies showed the opposite to be the case (Barro, 1991; Barro and Sala-i-Martin, 2004; Durlauf and Quah in: Sachverständigenrat, 2003)[4]. This led to the development of a new group of growth models known as the 'new' or 'endogenous' growth theory. Growth models in this category explain differences in growth rates between countries by differences in the growth of human capital and/or investment in R & D. This is to say that every country's growth rate converges to its long-run maximum growth rate which is given by its growth in human capital and investment in R & D. Steady-state growth rates vary for different countries due to varying initial levels of human capital and technical knowledge and their respective growth rates. The growth of human capital and technological progress takes over the role of the natural rate of growth as the growth rates of output, capital stock and consumption converge to it (Lucas, 1988; Romer, 1986, 1990; Barro, 1991; Barro and Sala-i-Martin, 2004).

However, these growth models also fail to appreciate a possible interdependence between the natural rate of growth and the actual rate of growth. The models have no role for aggregate demand in the long run, but rather rehabilitate the neoclassical growth model in this respect. The determinants of productivity growth (human capital and investment in R & D) are themselves determined by exogenous variables, namely by the preferences of profit-maximising economic agents.[5]

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[3] For a summary and critique of Solow's growth model see Hacche (1979); Hein (2004).

[4] Mankiv, Romer and Weil (1992) also examine the divergence of growth rates between countries. However, they defend the Solow model in many aspects while at the same time arguing that factors such as human capital formation and technological progress should not be neglected in the explanation of economic growth.

[5] For a more extensive critique of the endogenous growth theory see Hein (2004).

It was Kaldor (1957) who first attempted in his essay "A Model of Economic Growth" to construct a growth model which contains the interdependent relationships between the main factors determining the trend rate of growth such as the propensity to save, the flow of innovations, increases in the capital stock and the growth of population. Investment is understood by Kaldor as the result of entrepreneur's beliefs in continued growth in markets in the future. It reacts positively to increases in output in the past, while at the same time endogenously increasing future output. Kaldor was convinced that "the actual rate of progress of a capitalist economy is the outcome of the mutual interaction of forces which can adequately be represented only in the form of simple functional relationships […] rather than by constants" (Kaldor (1980), p. 259). These relationships are condensed in his technical progress function which postulates a positive relationship between the growth of capital per head and the growth of output per head. A higher rate of productivity growth can then only be achieved through a higher rate of capital growth. In a later model he combines the technical progress function with Verdoorn's Law (1949), which states that the growth of labour productivity is partly dependent on the growth of output itself through the process of increasing returns in the industrial sector (Kaldor, 1966).[6] It can then be shown that the actual rate of growth is the major determinant of labour productivity growth, rendering the natural rate of growth endogenous with respect to the actual rate of growth. High levels of demand in periods with high actual growth will then initiate cumulative growth processes as higher investment will cause labour productivity to increase faster, which in turn induces higher levels of output growth (Kaldor, 1966; Dixon and Thirlwall, 1975).[7]

There are various mechanisms which might cause the natural rate of growth to be endogenous to the actual rate of growth and explain Verdoorn's Law more in depth: First, the growth of the labour force increases as output growth is augmented during boom periods. There is more employment, hours worked as well as general participation rates of the population in the production process increase. Another important aspect might be increasing immigration of labourers during periods of high growth. Second, labour productivity is bound to rise faster in periods with increasing output growth due to increasing micro- and macro-economies of scale as well as dynamic economies of scale through embodied technical progress, reallocation of labour from sectors of low to those of high productivity, learning-by-doing and capital accumulation.

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[6] León-Ledesma (2000) stresses that increasing returns can also be found in the services sector and might explain regional differences in growth rates through labour mobility and the high labour intensiveness of work in the services sector. This sector thus constitutes another 'engine of growth' in the sense of Verdoorn's Law.

[7] A more extensive model which integrates also non-technical productive factors can be found in León-Ledesma (2002).

If the natural rate of growth reacts endogenously to changes in the actual rate, adjustment between both rates is made more difficult. As the actual rate diverges upwards from the warranted rate during boom periods, the natural rate also rises. The boom will generate its own supply until demand constraints related to inflation or balance of payments problems occur. Because this could happen before the full-employment ceiling is ever reached, the actual rate of growth might never rise to its natural rate. This might be an explanation to the fact that growth in boom periods is often accompanied by continuing unemployment. Also, a convergence of the warranted rate of growth to the natural rate is made more complicated if the natural rate shifts in the same direction as the actual rate. If the warranted rate exceeds the natural rate of growth, the capital stock grows faster than labour productivity. In order to adjust to the natural rate, the warranted rate would have to decline, but since a warranted rate above the natural rate implies conditions of depression, the natural rate is also likely to fall together with the actual rate (León-Ledesma and Thirlwall, 2002).

3. Empirical study

3.1 The model

After this brief theoretical summary, the model which is used to test for the endogeneity of the natural rate of growth with respect to the actual rate and to assess the causality between input growth and output growth is presented in this section.

Before analysing its endogeneity, the natural rate of growth has to be estimated first. As Thirlwall (1969) points out, it can be calculated by using Okun's equation as in Okun (1962), which states a relationship between the percentage change in the level of unemployment ($d(u)_t$) and the growth of real output or GDP (g_t):

$$d(u)_t = a - b * g_t \qquad (1)$$

By definition, the natural rate of growth is the rate of growth that keeps unemployment constant and is thus given by a/b. However, there exists the possibility of a downwards bias of the coefficients a and b due to labour hoarding and drop-outs from the labour force when there is no growth, leading to an overestimation of the natural rate of growth. This can be avoided by estimating

$$g_t = a_1 - b_1 * d(u)_t , \qquad (2)$$

where the natural rate is now defined by the constant a_1 (León-Ledesma and Thirlwall, 2002). Although both equation (1) and (2) were estimated, only the results for equation (2) are reported here, as these are considerably more robust than the results for equation (1) and thus seem more appropriate for further use in the following estimations.[8] Equation (2) is therefore used to calculate the natural rate for the countries in the sample. In order to test for the endogeneity of the natural rate of growth, a second system of equations is estimated adding a dummy variable to equation (2) which receives the value of one for boom periods where the natural rate of growth (a_1) lies above the actual rate of growth (g_t) and of zero otherwise:

(3) $$g_t = a_2 + b_2 * dummy_t - c_2 * d(u)_t$$

If both coefficients a_2 and b_2 are found to be significant and if the sum of both coefficients is significantly higher than a_1, the natural rate of growth in boom periods must have risen in comparison to the average natural rate of growth. Hence, in this case the natural rate of growth must be endogenous to the actual rate of growth.[9]

Finally, in addition to the endogeneity hypothesis, the direction of causality between national output and total factor inputs for some of the countries in the sample is also tested. The log of GDP ($LGDP_t$) is taken as the variable for the output, whereas the log of total factor inputs is estimated according to equation (4)

(4) $$LTFI_t = w * L_t + (1 - w) * K_t,$$

where L_t and K_t are the logarithms of the levels of labour and capital stock, respectively, and w is the labour income share (León-Ledesma and Thirlwall, 2002).

Both the logarithm of national output ($LGDP_t$) and the logarithm of total factor inputs ($LTFI_t$) are then tested for stationarity with an augmented Dickey-Fuller Test (ADF) and, if they are at least I(1) variables, i.e. first-difference stationary, a test for cointegration using the Engle-Granger-method is conducted:

[8] Results for the estimation of equation (1) are available from the author on request.

[9] In addition to equation (3), further dummies were constructed using an HP-filter and a five-year moving-average on the actual rate of growth. The dummy was assigned the value of one for periods where average actual rate of growth was higher than the HP-filter i.e. the moving-average. The results confirmed the findings of equation (3) and are available on request.

(5) $$LTFI_t = a_3 + b_3 * LGDP_t + ecm_t$$

If the residuals ecm_t from equation (5) are found to be stationary as can be tested with an ADF test with adjusted critical values, this points to the existence of a stationary relationship between the two variables and thus to cointegration between $LTFI_t$ and $LGDP_t$ (Hassler, 2000). According to Granger (1988), the existence of cointegration, i.e. of an equilibrium relationship, between two variables is equivalent to the fact that at least one of the variables must converge to the other so as to establish the equilibrium: “for a pair of series to have an attainable equilibrium, there must be some causation between them to provide the necessary dynamics” (Granger, 1988, p. 203).

In order to determine the direction of causality between inputs and output, the lagged residuals obtained from equation (5) are then included in an error correction model which is estimated twice, assuming each variable first to be exogenous and then to be endogenous:[10]

(6) $$d(LTFI)_t = a_4 + b_4 * ecm_{t-1} + \sum_{i=1}^{n}(c_{4i} * d(LTFI)_{t-i}) + \sum_{i=0}^{n}(d_{4i} * d(LGDP)_{t-i})$$

(7) $$d(LGDP)_t = a_5 + b_5 * ecm_{t-1} + \sum_{i=1}^{n}(c_{5i} * d(LGDP)_{t-i}) + \sum_{i=0}^{n}(d_{5i} * d(LTFI)_{t-i})$$

Granger causality from output growth to input growth can be proven to occur in the case of a significant coefficient b_4 for the estimation of equation (6). If this is the case, the log of total factor inputs is the dependent variable which converges to the equilibrium state between $LTFI_t$ and $LGDP_t$. If in addition to the coefficient b_4 the coefficients d_{4i} are found to be significant, strong exogeneity from $LGDP_t$ to $LTFI_t$ will emerge as described in Maddala (1989) and Urbain (1992). Reversing the variables in equation (7) will test for causality from $LTFI_t$ to $LGDP_t$.[11]

[10] The number of lags used for the differences of the endogenous and the exogenous variable in equation (6) and (7) was determined according to the ‘general to specific’ method which starts with a relatively high number of lags and eliminates coefficients which are found to be not significant. (Granger, 1997)

[11] Likewise, Kirchgässner and Wolters (2006) distinguish between Granger causality in the long run and in the short run: Granger causality from $LGDP_t$ to $LTFI_t$ will, thus, emerge in the long run if the coefficient b_4 in equation (6) is found to be significant, but the coefficients d_{4i} are not. Similarly, Granger causality will occur in the short run if the opposite is the case. However, the existence of a cointegration relationship between the two variables implies that Granger causality in the long run must exist at least in one direction.

In contrast to mainstream neoclassical growth theory, under the hypothesis of the endogeneity of the natural rate of growth, causality from output to inputs will generally be expected to occur. It is argued that the growth of demand is the main ‘engine for growth’ resulting in cumulative growth inducing higher investment and, thus, higher growth rates, until demand constraints bite. However, the possibility of bi-directional causality between input growth and output growth has to be considered for the following reasons: First, an increase in production implies an increase in capital and labour hired which might result in a short-run causality from inputs to output, depending on the time lag structure of the demand process. Second, an increase in capital might embody new techniques in the production process, leading to increased productivity and, hence, to an advantage in price and non-price competitiveness between countries. This, in turn, might result in more demand for exports so that an increase in capital might have a positive effect on output growth through higher demand for goods in the exports sector (León-Ledesma and Thirlwall, 2002).

3.2 Estimation of the natural rate of growth

The empirical study on the endogeneity of the natural rate of growth was conducted on a sample of eleven Latin American countries consisting of Argentina, Bolivia, Brazil, Chile, Costa Rica, Columbia, Mexico, Nicaragua, Paraguay, Peru and Venezuela. These countries can be regarded as a representative sample of all Latin American countries as they combine rather industrialised countries like Mexico and Brazil, as well as some of the poorest countries of the continent like Bolivia and Nicaragua. Also, the sample represents all Latin American regions and consists of large as well as small countries.

All time series for the estimations were obtained from the GlobalInsight database “World Market Monitor” which comprises, amongst others, databases from the OECD, the IMF and national institutions like central banks. The majority of the times series used in the estimations came from the IMF database, with the exception of the data for the annual growth of GDP for Costa Rica and Venezuela, which were obtained from the “Global Development Network Growth Database” of the Development Research Institute at the New York University. The period of the empirical study differs for the countries in the sample due to the difficulty in obtaining reliable data for some countries. The longest time series were available for Columbia (1979-2004), whereas for Bolivia data could only be acquired for the period from 1990 to 2003. Most of the time series used in the estimations cover the period from 1986 to 2003.

It has to be pointed out that due to the short time series in some cases, the results obtained in the estimations have to be interpreted carefully. Furthermore, it should be noted that the data for the GDP and the level of employment do not contain the relatively large part of production and employment taking place in the informal sector in many of the Latin-American countries in the sample. In addition, some of the estimations might show unstable results due to structural breaks in the time series which occurred as a consequence of debt and monetary crises, civil wars or natural catastrophes in some of the countries.

The results for the estimation of the natural rate of growth for the countries in the sample are shown in Table 3 which summarises the results for the estimation of equation (2). All equations were estimated simultaneously using seemingly unrelated regression (SUR) estimations as in Zellner (1962), with the advantage of increased efficiency for the estimation of the coefficients when compared to ordinary least squares regressions. It is possible to employ SUR estimations because the residuals from single OLS regressions for equation (2) can be shown to be significantly correlated in the majority of the estimations, considering the relatively small number of dates used in the regressions (Greene, 2003) (Table 1 in the appendix).[12]

After first estimating the coefficients a_1 and b_1 separately for each country in the SUR system, a Wald Test was conducted testing for equality of various coefficients. The results are reported in Table 2 (in the appendix) which illustrates that the null hypothesis of equal coefficients could not be rejected for the restrictions $a_1(ar) = a_1(bo) = a_1(br) = a_1(co) = a_1(pe)$; $b_1(ar) = b_1(br) = b_1(pe)$; $b_1(chi) = b_1(cr) = b_1(nic)$; $a_1(me) = a_1(nic) = a_1(par)$ and $b_1(me) = b_1(ven)$. Thus, in the SUR system, the results of which are presented in Table 3, the same natural rate of growth, represented by the coefficient a_1, was estimated for Argentina, Bolivia, Brazil, Columbia and Peru. Additionally, for Argentina, Brazil and Peru, the same slope coefficient b_1 was estimated in the system. For Mexico, Nicaragua and Paraguay it was also possible to estimate the same natural rate of growth. Furthermore, the same coefficient b_1 was estimated for Chile, Costa Rica and Nicaragua, as well as for Mexico and Venezuela.

[12] All equations were also estimated using simple OLS regressions and estimating all equations for each country separately. However, the estimations for the coefficients using SUR regressions were considerably more efficient and showed better results, so that only those will be discussed in this paper. Results of the OLS regressions are available from the author on request.

Some equations showed very low Durbin-Watson-Statistics indicating possible first order autocorrelation of the residuals and were thus corrected by including a lagged endogenous variable in the equation. We report long-run coefficients. In some cases, however, it was not possible to increase the values of the Durbin-Watson-Statistics with the estimation of a dynamic model as mentioned above. These equations were therefore tested for structural breaks using the CUSUM and the CUSUM of squares test, which showed no indication of structural breaks during the time span of the analysis. However, some countries had strong outliers in the residuals due to extreme economic crises. These were then eliminated with an additional dummy variable.

< *Table 3 here* >

All estimates of the natural rate of growth for the countries in the system, with the exception of Venezuela, are found to be highly significant at the 99% confidence level. These results are strengthened by a Wald Test testing for significance of the natural rate of growth (restriction: $a_1 = 0$), which cannot be rejected for any country in the sample. The average natural rate of growth for the countries in the time span covered in the analysis varies between 1.78% per year for Venezuela and 6.12% for Chile. The majority of natural growth rates range between 2.64% and 3.03% per annum. This reveals a relatively large diversity in the average potential growth for the Latin American countries which might be due to extreme economic crises suffered by some of the countries in the sample. Another important aspect with reference to the varying natural growth rates might be the differing stages of industrialisation realised by the countries.

Except for Paraguay, which shows no significant relationship between the annual growth of GDP and the change in the unemployment rate, the estimates for the slope coefficients b_1 are also significant for all the countries in the sample. The b_1 coefficient for Bolivia only shows significance at the 95% confidence level, indicating a slightly less stable relationship between the growth of output and the change in the unemployment rate. All other estimates for b_1 are highly significant at the 99% confidence level. Although the results for the adjusted R-squared are fairly low in the estimations of equation (2), the high significance of the coefficients on the whole suggests the model to be robust and reliable.

3.3 The endogeneity of the natural rate of growth

In the second step of the analysis the SUR system from equation (2) is estimated again adding a dummy variable for each country which takes on the value of one for boom periods in which the actual rate of growth lies above the natural rate estimated in equation (2). Thus, the endogeneity of the natural rate of growth can be analysed separately for each country, while at the same time taking advantage of the gain in efficiency for the estimations through the application of SUR regressions. The restrictions applied on the coefficients were the same as in the first SUR system. Again, some equations were corrected for autocorrelation using lagged endogenous variables. In those cases, we report the long-run coefficients. Again, the residuals of the equations revealed no indication of structural breaks, but in some cases had to be corrected for extreme outliers in order to avoid autocorrelation in the residuals. The results for the estimation of equation (3) are summarised in Table 4.

< *Table 4 here* >

All coefficients for the dummy variables, b_2, are found to be highly significant at the 99% confidence level. The majority of the coefficients for the constant, a_2, and the slope, c_2, are also significant at the 99% confidence level, confirming again the overall significance of the model. The constant a_2, which can be interpreted as the natural rate of growth in recession periods, is found insignificant in the cases of Mexico, Nicaragua and Paraguay and even negative (at the 95% confidence level) for Venezuela. This indicates a negative or zero natural rate of growth during recessions which points to a high sensitivity of potential growth with respect to actual growth. For Chile, Costa Rica and Nicaragua, the negative slope coefficients c_2 are quite small and only significant at the 90% confidence level. In the case of Bolivia, Columbia and Paraguay, the slope coefficients c_2 are insignificant because of very small negative slopes of the equations. With reference to the results for Paraguay in the estimation of equation (2), the results from equation (3) which finds a zero coefficient for the slope again points to the weak relationship between annual growth and changes in the unemployment rate for this country, so that results for Paraguay should be interpreted cautiously. Overall, the system shows very good results for the adjusted R-squared, especially when considering the relatively short time series employed in some of the estimations.

The natural rate of growth in boom periods is obtained from the sum of the coefficients for the constant and the dummy variable ($a_2 + b_2$). As shown in Table 4, it is considerably higher than the average natural rate of growth for all the countries in the sample, thus proving the endogeneity of the natural rate of growth with respect to the actual rate of growth. Similar to the results for equation (2), the estimates of the natural rate in boom periods show again a large range. Extremely high potential growth in boom periods is reported for Peru (7.96%), Chile (7.91%), Argentina (7.20%)and Costa Rica (6.81%), while the natural rates of Paraguay (4.54%) and Brazil (4.42%) amount to little more than half of the highest rates in the sample.

< Table 5 here >

Table 5 summarizes the results from equation (2) and (3) and reports the difference between the average natural rates and the respective natural rates in boom periods as well as the percentage increase between both rates. On the average, the natural rate of growth in the sample increases by 2.25 percentage points in boom periods, which equals an increase of 64.10%. However, while five out of eleven countries in the sample show relatively modest increases of the natural rate of growth in boom periods at about 30-50%, the other six countries display an extremely high sensitivity of the natural rate with respect to the actual rate of growth with increases in boom periods from 64% to over 150%. This is most evident in the cases of Venezuela (+159.55%), Argentina (+137.62%) and Nicaragua (+89.39%), where estimates of the natural rate of growth in boom periods nearly doubled or even tripled in comparison to those of the average natural rate. The fact that all the countries where the estimates of the natural rate of growth in recession periods (a_2) were insignificant or negative, belong to the second group with very high percentage increases in the natural rate confirms these results. They are considerably higher than the percentage increase in the natural rates of growth of the OECD countries studied by León-Ledesma and Thirlwall (2002) which points to a higher sensitivity of potential growth to demand for some developing countries. This might be due to the large proportion of the labour force employed in the informal sector or in the subsistence economy which can easily move into formal employment in boom periods. Also, the lower the level of development reached in an economy, the easier it is to gain remarkable increases in productivity with relatively small increases in investments. Furthermore, industries in less developed countries are generally more labour-intensive than those in industrialised countries which might further explain the comparably large decrease in the unemployment rate in periods of high growth. It is also certainly no coincidence that the countries with a very high sensitivity of the natural rate of growth with respect to the actual rate (Argentina, Bolivia, Mexico, Nicaragua, Paraguay and Venezuela) all show a relatively low level of industrialisation because they experienced severe debt and monetary crises, political turbulences and, in the case of Nicaragua, heavy destruction due to a natural catastrophe during the time span of the analysis (Easterly, 2002). Hence, they react much stronger to increasing demand in boom periods than relatively more developed countries.[13]

3.4 Granger causality analysis between input growth and output growth

Following the analysis of the endogeneity of the natural rate of growth, the causality between total factor inputs and national output was studied by conducting a Granger causality analysis. Due to the difficulty in obtaining data for the capital stock and the compensation of employees for many of the countries in the sample, the analysis of the direction of causality was performed only for the four countries Brazil, Columbia, Mexico and Peru. Data for the level of employment, compensation of employees and gross investment were available from the IMF database. The time series for the capital stock and the labour income share, however, had to be constructed according to the following definitions:

Labour income share:

$$w_t = \frac{wages_t}{netGDP_t}$$

Capital stock:

$$K_t = I_t + (1-\theta) * K_{t-1}$$

Where K_t = capital stock in year t, I_t = gross fixed capital formation in year t and θ = depreciation rate, which in conformity with Hernández-Catá (2000) was assumed to be 10% per annum. The initial capital stock was for reasons of simplicity taken to be equal for all four countries. As for the causality analysis only the logarithms of the level of capital stock were applied, differences in the level of capital stock had no effect on the results of the analysis.

The period over which the analysis was carried out varies for each country due to the difficulty in obtaining reliable data for some of the countries. The majority of the estimations were made for the period of 1986-2003. The longest time series could be obtained for Columbia (1979-2004), whereas the shortest period is that of Bolivia (1990-2003).

[13] For a summary of economic and political developments in the Latin-American countries since the 1980s see Ehrke, 1989; Volger, 1989; Kraemer, 1995; and Hujo, 2005.

After constructing the variables $LGDP_t$ and $LTFI_t$, they were tested separately for unit roots employing an Augmented Dickey-Fuller test (ADF). Table A1 in the appendix lists the results for the ADF tests. Almost all the variables turned out to be I(1), i.e. first difference stationary, except for the $LGDP_t$ of Columbia which seems to be I(2). Some of the time series tested are very short, so that the results of the ADF test can only be interpreted cautiously. However, keeping this in mind, it still seems reasonable to assume all the variables to be I(1) for the following analysis. This finding also coincides with the results from León-Ledesma and Thirlwall (2002).

In order to determine whether there exists a cointegration relationship between inputs and output, the residuals (ecm_t) from equation (5) were also tested for stationarity using an ADF test without intercept. The results from the tests are summarised in Table A2 in the appendix and indicate cointegration between $LTFI_t$ and $LGDP_t$ for each country in the causality analysis. In all four cases, the null hypothesis of the existence of a unit root for the residuals from equation (5) is rejected at the 99% confidence level. Since the finding of a cointegration relationship between inputs and output implies that causality must exist at least in one direction (Granger, 1988), error correction models are applied in the following to determine the direction of causality.

< Table 6 here >

The results for the estimation of equation (6) which tests for causality from output to inputs are reported in Table 6. Since the analysis was conducted for only four countries, the error correction models are estimated using simple OLS regressions. For all the four countries in the analysis, the coefficient b_4 of the error correction term ecm_{t-1} is significant at least at the 95% confidence level. In the cases of Columbia and Mexico, it is highly significant at the 99% confidence level. The coefficients d_{4i} of the lagged differences of LGDP are also significant at least at the 90% confidence level in every error correction model. These results are further confirmed by a Wald Test which tests for the joint significance of the coefficients b_4 and d_{4i} (restriction: $b_4 = d_{4i} = 0$), which can be rejected for all the countries. Granger causality in the long run as in Kirchgässner/Wolters (2006) or strong exogeneity from output growth to input growth as in Maddala (1989) and Urbain (1992) is thus strongly suggested by these results. Despite the short time series and the construction of the data, the equations seem to be fairly well specified and robust. Although estimations for Brazil and Columbia show relatively low values for the adjusted R-squared, neither the Durbin-Watson-Statistics, nor the results for the Ramsey RESET Test, the Q-Statistics or the results for the White Test indicate any major flaws in the residuals such as autocorrelation or heteroskedasticity.

< *Table 7 here* >

Table 7 lists the results of the reversed error correction models, testing for causality from $LTFI_t$ to $LGDP_t$. In contrast to the findings for the estimation of equation (6), the results for equation (7) are less significant. The coefficients of the lagged residuals from equation (5) are significant only for Mexico (at the 99% confidence level) and for Brazil (at the 95% confidence level), whereas the regressions for Columbia and Peru yield no significant results. Except for Columbia, coefficients for various lags of d(LTFI) are significant at least at the 90% confidence level, pointing at possible Granger causality from input growth to output growth in the long run for Brazil and Mexico, and in the short run for Peru. Due to the high significance of the d_{5i} coefficients for Peru and the joint significance of both b_5 and d_{5i} coefficients in the case of Brazil and Mexico, the null hypothesis of no joint significance in the Wald Test can be rejected. Thus, only for Columbia Granger causality from $LTFI_t$ to $LGDP_t$ is clearly denied. However, the estimations of equation (7) for both Mexico and Peru reject the null hypothesis of the Ramsey RESET Test although there is no evidence of autocorrelation or heteroskedasticity in the residuals. This points at a general misspecification of the error correction model, making it unlikely for the results to be reliable. Therefore, the existence of long-run Granger causality from input growth to output growth as suggested by neoclassical and ‘endogenous’ growth theories can only be proven reliably in the case of Brazil. A lower R-squared and rejection of the Wald Test at the 90% instead of the 95% confidence level, however, suggests that causality from output to inputs in the case of Brazil might be stronger than the reverse.

4. Conclusions

In this paper, an analysis of the hypothetical endogeneity of the natural rate of growth and of the direction of causality between total factor inputs and national output for Latin-American countries was attempted.

While mainstream neoclassical and ‘endogenous’ growth theories expect potential growth to be determined independently of demand factors, the empirical analysis demonstrated that, at least for this sample of Latin-American countries, natural rates of growth react strongly positively to higher actual growth rates determined by accelerating demand in boom periods.

Thus the initial hypothesis was confirmed. Moreover, the estimations for some of the countries yielded much higher estimates for the natural rate in boom periods than those for the OECD countries by León-Ledesma and Thirlwall (2002) and, accordingly, very high percentage increases of the natural rate with reference to its average value. It seems that due to a low level of industrialisation and production resulting from debt and monetary crises and other destabilising developments in the recent past, many of the less developed countries in Latin-America react very sensitively to increases in actual growth. The demand factors which can cause cumulative growth processes through more investment and higher productivity growth thus show the more impact, the lower the initial level of productivity is.

The second hypothesis concerning the direction of causality between inputs and output could also be confirmed empirically. In contrast to mainstream growth theory which argues that causality runs only from inputs to output, because the growth process is solely supply-side determined, the analysis revealed a much stronger Granger causality from output growth to input growth. The existence of causality in the long run from the logarithms of GDP to the logarithm of total factor inputs could be confirmed for all the countries in the analysis, while estimating the reverse relationship yielded insignificant or misspecified result. Only in the case of Brazil could bi-directional causality in the long run not be rejected. However, results from equation (6) seem more robust, suggesting causality from output growth to input growth to be stronger than the reverse.

The empirical results emphasize the importance of sustaining high levels of internal and external demand for goods and services. The endogeneity of the natural rate of growth implies that automatic convergence of the actual rate to the steady-state equilibrium cannot be expected. Consequently, cumulative growth processes can be initiated, which, through higher growth of demand in boom periods, enhance endogenously both employment and the growth of productivity. However, in order to secure a sustained high level of demand in the Latin-American countries, several conditions would have to be met. First, the large gap in the distribution of income between the poor masses and the elite would have to be diminished substantially in order to create a high level of demand for domestic goods. Second, a higher level of education and political stability would have to be established in order to facilitate the creation of an industrial sector for the production of export goods.

If economic policy in the countries of the Latin-American continent concentrated on the mentioned fields of activity, it might be possible to raise the level of growth in the long run through the endogenous increase of the natural rate of growth.

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Table 1: Correlation matrix of the residuals from equation (2) using OLS regressions

Residuals for	Argentina	Bolivia	Brazil	Chile	Columbia	Costa Rica	Mexico	Nicaragua	Paraguay	Peru	Venezuela
Argentina	1.000	0.018	0.310	0.837	0.613	0.086	0.299	0.548	0.344	0.643	-0.176
Bolivia	0.018	1.000	0.404	0.315	0.405	-0.006	-0.099	-0.059	0.204	-0.012	0.140
Brazil	0.310	0.404	1.000	0.434	0.150	-0.097	-0.190	0.600	0.175	0.690	-0.088
Chile	0.837	0.315	0.434	1.000	0.674	0.119	0.091	0.394	0.279	0.503	0.065
Columbia	0.613	0.405	0.150	0.674	1.000	-0.005	0.030	0.239	0.616	0.427	0.193
Costa Rica	0.086	-0.006	-0.097	0.119	-0.005	1.000	-0.255	-0.069	0.020	0.119	-0.187
Mexico	0.299	-0.099	-0.190	0.091	0.030	-0.255	1.000	-0.003	-0.328	-0.082	-0.193
Nicaragua	0.548	-0.059	0.600	0.394	0.239	-0.069	-0.003	1.000	0.195	0.680	-0.101
Paraguay	0.344	0.204	0.175	0.279	0.616	0.020	-0.328	0.195	1.000	0.290	0.357
Peru	0.643	-0.012	0.690	0.503	0.427	0.119	-0.082	0.680	0.286	1.000	-0.239
Venezuela	-0.176	0.140	-0.088	0.065	0.193	-0.187	-0.193	-0.101	0.357	-0.239	1.000

Table 2: Results for a Wald Test testing for the equality of coefficients in the SUR system for equation (2) $g_t = a_1 - b_1 * d(u)_t$

Restriction	Wald Test (prob. for $\chi^2(1)$)
$a_1(ar) = a_1(bo) = a_1(br) = a_1(co) = a_1(pe)$	0.988
$b_1(ar) = b_1(br) = b_1(pe)$	0.712
$b_1(chi) = b_1(cr) = b_1(nic)$	0.680
$a_1(me) = a_1(nic) = a_1(par)$	0.929
$b_1(me) = b_1(ven)$	0.839

Country codes: ar = Argentina, bo = Bolivia, br = Brazil, chi = Chile, cr = Costa Rica, co = Columbia, me = Mexico, nic = Nicaragua, par = Paraguay, pe = Peru, ven = Venezuela

Table 3: Estimation of the natural rate of growth

Results for equation (2) $g_t = a_1 - b_1 * d(u)_t$. In the case of first order autocorrelation, equation (2a) $g_t = a_1 - b_1 * d(u)_t + c_1 * g_{t-1}$ was estimated.

Country	Coefficient a_1	Coefficient b_1	Coefficient of g_{t-1} (c_1)	Natural rate of growth	Adjusted R^2	Durbin-Watson-Statistic	Wald Test ($\chi^2(1)$)
Argentina	3.026*** (0.234)	-1.702*** (0.252)	/	3.03%	0.221	1.561	167.955***
Bolivia	3.026*** (0.234)	-0.565** (0.241)	/	3.03%	0.024	1.828	167.955***
Brazil	3.026*** (0.234)	-1.702*** (0.252)	/	3.03%	0.339	1.613	167.955***
Chile	3.957*** (0.910)	-1.591*** (0.264)	0.353*** (0.130)	6.12%	0.403	1.866	69.890***
Columbia[1]	3.026*** (0.234)	-0.438*** (0.150)	0.208*** (0.066)	3.82%	0.612	1.638	203.141***
Costa Rica	4.768*** (0.473)	-1.591*** (0.264)	/	4.77%	0.174	1.633	101.529***
Mexico[2]	2.641*** (0.238)	-2.704*** (0.268)	/	2.64%	0.700	2.081	123.062***
Nicaragua	2.641*** (0.238)	-1.591*** (0.264)	/	2.64%	0.127	1.514	123.062***
Paraguay	2.641*** (0.238)	-0.171 (0.311)	/	2.64%	-0.083	1.239	123.062***
Peru[3]	3.026*** (0.234)	-1.702*** (0.252)	0.410*** (0.119)	5.13%	0.464	1.748	22.590***
Venezuela	1.781** (0.776)	-2.704*** (0.268)	/	1.78%	0.610	1.377	5.270**

Notes: 1) Coefficients: standard errors in parentheses, * denotes significance at the 90% confidence level, ** denotes significance at the 95% confidence level, *** denotes significance at the 99% confidence level.
2) The natural rate of growth can be derived from the constant a_1. This is the rate of growth that keeps unemployment constant. (Thirlwall (1969)) For equations which had to be corrected for first order autocorrelation, the natural rate of growth can be calculated from $a_1/(1-c_1)$.
3) The results reported for the Wald Test test for the significance of the natural rate of growth (restriction: $a_1 = 0$).
[1] A dummy was included to correct for the outlier in 1999.
[2] A dummy was included to correct for the outlier in 1986.
[3] A dummy was included to correct for the outlier in 1988.

Table 4: Testing for the endogeneity of the natural rate of growth

Results for equation (3) $g_t = a_2 + b_2 * dummy_t - c_2 * d(u)_t$. In the case of first order autocorrelation, equation (3a) $g_t = a_2 + b_2 * dummy_t - c_2 * d(u)_t + d_2 * g_{t-1}$ was estimated.

Country	Coefficient a_2	Coefficient b_2	Coefficient c_2	Coefficient of g_{t-1} (d_2)	Natural rate of growth in boom periods	Adjusted R^2	Durbin-Watson-Statistics
Argentina	1.004*** (0.238)	6.192*** (0.958)	-0.840*** (0.188)	/	7.20%	0.553	1.429
Bolivia	1.004*** (0.238)	3.186*** (0.359)	-0.030 (0.116)	0.158* (0.085)	4.98%	0.674	1.597
Brazil	1.004*** (0.238)	3.458*** (0.500)	-0.840*** (0.188)	/	4.42%	0.626	1.416
Chile	3.197*** (0.553)	4.715*** (0.694)	-0.488** (0.218)	/	7.91%	0.682	2.424
Columbia[1]	1.004*** (0.238)	4.208*** (0.462)	-0.157 (0.183)	/	5.21%	0.611	1.460
Costa Rica	2.816*** (0.404)	3.996*** (0.537)	-0.488** (0.218)	/	6.81%	0.621	1.752
Mexico	-0.116 (0.283)	4.655*** (0.495)	-1.323*** (0.240)	/	4.66%	0.739	1.912
Nicaragua	-0.116 (0.283)	4.998*** (1.222)	-0.488** (0.218)	/	5.00%	0.426	1.735
Paraguay[2]	-0.116 (0.283)	3.346*** (0.345)	-0.067 (0.126)	0.263*** (0.082)	4.54%	0.722	1.849
Peru	1.004*** (0.238)	4.632*** (0.834)	-0.840*** (0.188)	0.292*** (0.076)	7.96%	0.679	1.790
Venezuela	-2.040** (0.825)	6.664*** (1.030)	-1.323*** (0.240)	/	4.62%	0.770	0.869

Notes: 1) Coefficients: standard errors in parentheses, * denotes significance at the 90% confidence level, ** denotes significance at the 95% confidence level, *** denotes significance at the 99% confidence level. 2)The natural rate of growth in boom periods is derived from the sum of the coefficients a_2 and b_2. For equations which had to be corrected for first order autocorrelation, the natural rate of growth can be calculated from $(a_2+b_2)/(1-d_2)$.

[1] A dummy was included to correct for the outlier in 1999.

[2] A dummy was included to correct for the outlier in 2002.

[3] A dummy was included to correct for the outlier in 1988.

Table 5: Sensitivity of the natural rate of growth to the actual rate of growth				
Country	Natural rate of growth (equation (2))	Natural rate of growth in boom periods		
		equation (3)	absolute difference (3)-(2)	% increase (3)-(2)
Argentina	3.03	7.20	4.17	137.62
Bolivia	3.03	4.98	1.95	64.36
Brazil	3.03	4.42	1.39	45.87
Chile	6.12	7.91	1.79	29.25
Columbia	3.82	5.21	1.39	36.39
Costa Rica	4.77	6.81	2.04	42.77
Mexico	2.64	4.66	2.02	76.52
Nicaragua	2.64	5.00	2.36	89.39
Paraguay	2.64	4.54	1.90	71.97
Peru	5.13	7.96	2.83	55.17
Venezuela	1.78	4.62	2.84	159.55
Average	3.51	5.76	2.25	64.10

Table 6: Testing for causality from $LGDP_t$ to $LTFI_t$

Results for equation (6) $d(LTFI)_t = a_4 + b_4 * ecm_t + \sum_{i=1}^{n}(c_{4i} * d(LTFI)_{t-i}) + \sum_{i=1}^{n}(d_{4i} * d(LGDP)_{t-i})$.

Country	Coefficient b_4	Coefficients d_{4i}	Number of Lags estimated for d(LGDP)	Adjusted R^2	Durbin-Watson-Statistics	Ramsey RESET Test (prob. for F-Statistics)	Q-Statistics (prob. for lag = 1)	White Test (prob. for F-Statistics)	Wald Test (prob. for $\chi^2(1)$)
Brazil	-0.358** (0.146)	0.576* (0.375)	t	0.252	1.679	0.641	0.507	0.558	0.021
Columbia	-0.477*** (0.161)	-0.673** (0.306)	t-3	0.307	1.876	0.830	0.916	0.674	0.011
Mexico	-0.475*** (0.063)	0.387*** (0.040) -0.203*** (0.061)	t; t-2	0.859	1.750	0.726	0.655	0.785	0.000
Peru	-0.410** (0.175)	-1.201* (0.563)	t	0.661	1.818	0.260	0.960	0.452	0.000

Notes: 1) Coefficients: standard errors in parentheses, * denotes significance at the 90% confidence level, ** denotes significance at the 95% confidence level, *** denotes significance at the 99% confidence level.
2) The results reported for the Wald Test test for the joint significance of the coefficients b_4 and d_{4i} (restriction: $b_4 = d_{4i} = 0$).

Table 7: Testing for causality from $LTFI_t$ to $LGDP_t$

Results for equation (7) $d(LGDP)_t = a_5 + b_5 * ecm_t + \sum_{i=1}^{n}(c_{5i} * d(LGDP)_{t-i}) + \sum_{i=1}^{n}(d_{5i} * d(LTFI)_{t-i})$.

Country	Coefficient b_5	Coefficients d_{5i}	Number of Lags estimated for d(LTFI)	Adjusted R^2	Durbin-Watson-Statistics	Ramsey RESET Test (prob. for F-Statistics)	Q-Statistics (prob. for lag = 1)	White Test (prob. for F-Statistics)	Wald Test (prob. for $\chi^2(1)$)
Brazil	0.327** (0.140)	0.377* (0.193) -0.313* (0.181)	t; t-3	0.159	2.023	0.686	0.928	0.607	0.088
Columbia	0.024 (0.118)	/	/	0.156	1.978	0.878	0.994	0.720	0.839
Mexico	1.116*** (0.163)	2.228*** (0.231) -0.695** (0.270) 0.819*** (0.172)	t; t-2; t-3	0.846	1.790	0.035	0.704	0.500	0.000
Peru	-0.036 (0.083)	0.223* (0.127) -0.666*** (0.101)	t-2; t-3	0.802	2.450	0.003	0.124	0.806	0.000

Notes: 1)Coefficients: standard errors in parentheses, * denotes significance at the 90% confidence level, ** denotes significance at the 95% confidence level, *** denotes significance at the 99% confidence level.
2) The results reported for the Wald Test test for the joint significance of the coefficients b_5 and d_{5i} (restriction: $b_5 = d_{5i} = 0$).

6. Appendix

Table A1: Results for the Augmented Dickey-Fuller tests (ADF) of the variables $LGDP_t$ (log of GDP) and $LTFI_t$ (log of Total Factor Inputs)

Null hypothesis: The variable has a unit root.

Country	Variable	ADF (t-statistic)	Number of lags (selected by the Schwartz information criterion)
Brazil	$LGDP_t$	-2.957*	0
	$d(LGDP)_t$	-3.902**	0
	$LTFI_t$	-2.750	6
	$d(LTFI)_t$	-3.532*	0
Columbia	$LGDP_t$	-3.023	4
	d(LGDP)t	-2.778	0
	$d(d(LGDP))_t$	-6.340**	0
	$LTFI_t$ (sample too small)	-3.746	5
	$d(LTFI)_t$	-4.449**	0
Mexico	$LGDP_t$	-2.558	1
	$d(LGDP)_t$	-5.710**	1
	$LTFI_t$	-3.812*	1
	$d(LTFI)_t$	-5.484**	1
Peru	$LGDP_t$	-4.170*	2
	$d(LGDP)_t$	-7.124**	3
	$LTFI_t$(sample too small)	-3.288	4
	$d(LTFI)_t$	-4.072**	0

Notes: * H_0 can be rejected at the 95% confidence level, ** H_0 can be rejected at the 99% confidence level.

Table A2: Results for the ADF for the residuals of equation (5) (ecm_t)

Null hypothesis: The variable has a unit root.

Country	Variable	ADF (t-statistic)	Number of lags (selected by the Schwartz information criterion)
Brazil	ecm	-3.887**	3
Columbia	ecm	-4.827**	7
Mexico	ecm	-4.835**	0
Peru	ecm	-3.064**	7

Notes: * H_0 can be rejected at the 95% confidence level, ** H_0 can be rejected at the 99% confidence level.